Language in Schizophrenia and Aphasia: the Relationship with Non-verbal Cognition and Thought Disorder

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Abstract

Objective: To determine the relationship between language abnormalities and broader cognitive impairment and thought disorder by examining language and cognition in schizophrenia and aphasia (a primary language disorder).

Methods: Cognitive and linguistic profiles were measured with a battery of standardised tests, and compared in a clinical population of n=50 (n=30 with schizophrenia and n=20 with aphasia) and n=61 non-clinical comparisons (n=45 healthy controls and n=16 non-affected first-degree relatives of patients with schizophrenia).

Results: Both clinical groups showed linguistic deficits. Verbal impairment was more severe in participants with aphasia, whereas non-verbal performance was more affected in participants with schizophrenia. In schizophrenia, but not in aphasia, verbal and non-verbal performance were associated. Formal thought disorder was associated with impairment in executive function and in grammatical, but not naming, tasks.

Conclusion: While patients with schizophrenia and aphasia showed language impairments, the nature and cognitive basis of these impairments may be different; language performance disassociates from broader cognitive functioning in aphasia but may be an intrinsic expression of a broader cognitive impairment in schizophrenia. Thought disorder may represent a core malfunction of grammatical processing. Results suggests that communicative ability may be a valid target in cognitive remediation strategies in schizophrenia.

Keywords: schizophrenia; aphasia; thought disorder; language; cognition

Introduction

Patients with schizophrenia typically show widespread cognitive impairment, spanning verbal and non-verbal abilities (Reichenberg & Harvey, 2007; Schaefer, Giangrande, Weinberger, & Dickinson, 2013). There appear to be particular deficits in executive function (EF) and semantic processing (Doughty & Done, 2009; Lawrence, Doughty, Al-Mousawi, Clegg, & Done, 2007; Reichenberg & Harvey, 2007), which appear independent of a generalised cognitive impairment (Weickert et al., 2000). Cognitive impairment is consistently found across various assessment methods and cultures (Schaefer et al., 2013) and in those at high risk of schizophrenia, including unaffected first-degree relatives (FDRs) of patients with schizophrenia (Bora et al., 2014). It is arguably a core component of the disorder and is associated with poor functioning and decreased quality of life (Mohamed et al., 2008; Sheffield et al., 2014). Formal thought disorder (FTD) refers to disorganised thought as evidenced by abnormal speech (Roche, Creed, Macmahon, Brennan, & Clarke, 2015), and seems to be associated with greater cognitive deficit in schizophrenia, particularly in semantic processing and EF (Bora, Yalincetin, Binnur, & Alptekin, 2019; Stirling, Hellewell, Blakey, & Deakin, 2006).

Schizophrenia, particularly in those with FTD (Barrera, McKenna, & Berrios, 2005; Rodriguez-Ferrera, McCarthy, & McKenna, 2001; Tan, Yelland, & Rossell, 2016), is also associated with a range of abnormalities in language production and comprehension, including impaired phonology, semantics, grammar, syntax, and pragmatic ability (Bambini et al., 2016; Condray, Steinhauer, van Kammen, & Kasparek, 2002; DiSimoni, Darley, & Aronson, 1977). Deficits in lexical-semantic retrieval are apparent, with some evidence of impaired naming ability (Leeson, Laws, & McKenna, 2006), and studies demonstrate abnormal speech patterns, including aberrant use of pronouns, abnormal syntactic structure, and reduced sentence complexity (Condray et al., 2002; DeLisi, 2001; Fineberg et al., 2015; Kuperberg, 2010; Oh, McCarthy, & McKenna, 2002; Stirling et al., 2006). Poverty of content of speech (e.g. empty speech, alogia), incoherence (e.g. word salad, incomprehensible speech), and neologisms and word approximations (making up new words) have also been reported in people with schizophrenia (McKenna & Oh, 2005). Language impairment in schizophrenia is consistent across cultures (Kim et al., 2015; Sumiyoshi et al., 2005), is associated with poor functioning and quality of life (Bowie & Harvey, 2008; Tan, Thomas, & Rossell, 2014), and is found in FDRs (Bedi et al., 2015). However, the exact picture of the language impairment is unclear, particularly in naming ability and sentence comprehension, where some studies find impairments in people with schizophrenia (with and without FTD), while others do not (Barrera et al., 2005; Bora et al., 2019; Goldberg et al., 1998; Leeson et al., 2006; Rodriguez-Ferrera et al., 2001; Stirling et al., 2006).

These language abnormalities have led some to characterise schizophrenia as a disorder of language, with linguistic impairments and disorganisation playing a causal role in the pathogenesis of schizophrenia and in symptoms in other apparently non-linguistic domains such as altered perceptions (Crow, 2008; Hinzen & Rosselló, 2015; Landre, Taylor, & Kearns, 1992; Tan et al., 2016; Zimmerer, Watson, Turkington, Ferrier, & Hinzen, 2017). It has been argued that thought in humans is intrinsically linguistic (Hinzen, Rosselló, & McKenna, 2016) and that linguistic abnormalities play a causal role in the development of FTD and delusions (Hinzen & Rosselló, 2015). These include loss of the referent in noun phrases, reduced syntactic complexity, including fewer clausal combinations, a lack of clausal embedding, and reduced figurative language (Çokal et al., 2018; Fraser, King, Thomas, & Kendell, 1986; Oh et al., 2002; Sevilla et al., 2018; Titone, Libben, Niman, Ranbom, & Levy, 2007). The apparent association of the origin of schizophrenia with the evolution of human language has been cited as providing further support for the

pathogenic salience of language impairments (Crow, 2008; Palaniyappan et al., 2013). In line with this, patients with schizophrenia and FTD show altered structure and activation in brain areas associated with language (Kircher, Oh, Brammer, & McGuire, 2005; Li et al., 2007).

An alternative view is that the language abnormalities in schizophrenia are an expression of disordered thinking (Bleuler, 1950) or cognitive impairment, particularly disorganised semantic memory (Goldberg et al., 1998; Leeson et al., 2006; Sumiyoshi et al., 2005), working memory and EF (Harrow et al., 2003; Kuperberg, 2010; Rodriguez-Ferrera et al., 2001). However, there is a complex interplay between language and non-verbal cognition. For example, inner speech and phonological working memory may be important in some cognitive tasks (Clark, 1998) and may underpin complex reasoning (Baldo et al., 2005). Language processing is also integrated with aspects of EF such as inhibition and there is a close relationship in their underpinning neural mechanisms (Fedorenko & Varley, 2016).

This debate regarding the necessary role of language in thought (Crow, 1998; Fedorenko & Varley, 2016; Kleist, 1914) invites comparison with aphasia, a primary language impairment resulting from brain injury. Typically, people with aphasia achieve lower EF and memory scores than neurotypical controls and some studies suggest that aphasia severity correlates with non-verbal cognitive performance (Baldo, Paulraj, Curran, & Dronkers, 2015; Fonseca, Ferreira, & Martins, 2017). However, there are also cases of people with severe aphasia who, on carefully designed tasks that remove demand for language processing, display intact thinking processes (Willems, Benn, Hagoort, Toni, & Varley, 2011). These results might suggest considerable autonomy between language and reasoning (Varley, 2014). Speech and language abnormalities observed in schizophrenia and FTD, are reported to be similar to those found in fluent, semantic aphasia (Faber et al., 1983; Landre et al., 1992; Taylor, 1999). Patients with schizophrenia and FTD tend to score below average on aphasia batteries (Dickerson, Boronow, Ringel, & Parente, 1999), display verbal comprehension deficits (DiSimoni et al., 1977; Halpern & McCartin-Clark, 1984) and impairment in semantic sorting tasks (Kelter, Cohen, Engel, List, & Strohner, 1977) that are similar to those of aphasic patients, and show structural and functional abnormalities in brain areas associated with aphasia (Kircher et al., 2001; Palaniyappan et al., 2013; Sans-Sansa et al., 2013).

One way to shed light on the potentially causal role of language disruption on thought and cognition, then, would be to directly compare patients with schizophrenia with (SZ+FTD) and without (SZ-FTD) FTD, and patients with aphasia, on a range of verbal and non-verbal cognitive domains that are considered to be impaired in schizophrenia: intelligence, EF, semantic memory, sentence comprehension, and naming (Barrera et al., 2005; Leeson et al., 2006; Rodriguez-Ferrera et al., 2001; Schaefer et al., 2013; Stirling et al., 2006). Since FDRs tend to show moderate cognitive impairment, it is also of interest to test this group. We hypothesised that: H1) schizophrenia would be associated with deficits across all tests and FDRs would show smaller impairments; H2) SZ+FTD would score lower than SZ-FTD and controls on all tests; H3) the verbal profile in aphasia would mirror the SZ+FTD profile more closely than the SZ-FTD profile (i.e. there will be fewer group differences between aphasia and SZ+FTD as compared to aphasia vs SZ-FTD on verbal tasks) and H4) verbal performance would correlate with non-verbal performance in both schizophrenia groups but less so in aphasia.

Materials and Methods

Participants

Thirty patients with schizophrenia were recruited from Northumberland Tyne and Wear NHS Mental Health Foundation Trust through care coordinators. Inclusion criteria comprised a diagnosis of schizophrenia in line with DSM-IV (American Psychiatric Association, 2000) criteria and a score ≥60 on the Positive and Negative Syndrome Scale (PANSS; a measure of global symptom severity) (Kay, Fiszbein, & Opler, 1987). Degree of FTD was measured with the Conceptual Disorganisation (CD) question of the PANSS, which specifies a "disorganised process of thinking characterised by disruption of goal directed sequencing e.g. circumstantiality, tangentiality, loose associations, non sequiturs, gross illogicality, or thought block". CD is rated on a scale of 1 (Absent) to 7 (Extreme). The SZ+FTD group comprised 15 patients with moderate to severe FTD (CD score ≥ 4) and the SZ-FTD group comprised 15 patients with, at most, minimal FTD (CD score < 4). Sixteen age-matched FDRs of patients with schizophrenia and 15 aged-matched healthy controls (HC) with no history of psychosis were recruited via community-based groups. Exclusion criteria for all participants included: a primary diagnosis of alcoholism or substance dependence; pervasive developmental disorder interfering with language skills; organic disease of the brain including significant head injury, stroke, tumour and epilepsy; and severe dyslexia.

Twenty patients diagnosed with aphasia following left hemisphere stroke were recruited through University College London's (UCL) communication clinic and UK Connect. All were in the chronic phase of recovery (mean 76.2 months post-onset; SD=63.3). This group were older than the schizophrenia group, so 30 controls age-matched to the aphasia patients were recruited from community-based groups in London. All participants were native English speakers, aged 16 and above, had normal, or corrected-to-normal, vision, and reported either no, or corrected, hearing impairment. A favourable ethics opinion was obtained from the National Research Ethics Service Committee North East - Newcastle and North Tyneside 2 and UCL Ethics Committee. Written informed consent was obtained from each participant.

Materials and Measures

For participants with schizophrenia and matched HCs, the National Adult Reading Test (NART; Nelson & Willison, 1991) was used to estimate premorbid intelligence (pmIQ). The Wechsler Abbreviated Scale of Intelligence - Second Edition (WASI-II; Wechsler, 2011) was used to measure current intelligence, which incorporates non-verbal intelligence (Perceptual Reasoning Index; PRI; calculated from Block Design and Matrix Reasoning sub-test scores) and verbal intelligence (Verbal Comprehension Index; VCI; calculated from Vocabulary and Similarities sub-test scores). Block Design requires participants to recreate a design using coloured blocks within a time limit, measuring visuospatial capacity and abstract reasoning. In Matrix Reasoning, participants complete a series of visual matrices, measuring abstract problem solving. WASI-II Vocabulary evaluates word knowledge and verbal concept formation through picture naming and word meaning definition. In Similarities, participants select words describing objects that share common characteristics with a target object and describe how two words are similar in meaning, measuring verbal concept formation and reasoning.

The Brixton Spatial Anticipation Test (Burgess & Shallice, 1997) was used as a non-verbal measure of EF. In this task, participants view arrays of circles of which one is coloured. The position of the coloured circle changes and is governed by a series of rules that alter without warning. Participants predict where

the next coloured circle will appear by pointing to the location, having to quickly adapt to rule changes. The Pyramids and Palm Trees test (PPT; picture version; Howard & Patterson, 1992) was used as a non-verbal measure of picture-semantic memory. Participants decide which of two pictures is associated with a target item and point to their chosen answer. The Test for Reception of Grammar (TROG-2; Bishop, 2003) measures sentence comprehension. The experimenter reads out sentences that increase in grammatical complexity and participants choose which of four pictures matches the stimulus sentence. The Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) measures lexical retrieval through picture naming.

Aphasic participants and matched HCs were not assessed on verbal IQ, as language impairment confounds measurement of intelligence/reasoning, nor on Block Design, due to comorbid motor deficits. The condensed test battery employed for aphasic participants and their controls therefore comprised WASI-II Matrix Reasoning, Brixton, PPT, BNT, and TROG-2.

Procedure

Participants with schizophrenia, FDRs and matched controls were tested in Newcastle University. Participants with aphasia and matched controls were tested in UCL, except one aphasic participant who was tested at home because of mobility problems. All clinical and cognitive assessments were completed by trained researchers. Each test was administered and scored according to its manual. All procedures were carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Statistical Analyses

Group differences were tested using Analysis of (Co)Variance (AN(C)OVA), followed by post-hoc tests using Fisher's Least Significant Difference. Outliers were changed to the next highest/lowest value (Winsorized) to retain sample size and information about rank (Osborne, 2013). In the event of heterogeneity of variances, Welch's ANOVA and Games-Howell post-hoc tests were used and corrected degrees of freedom were reported. Some data were transformed to correct for violations of AN(C)OVA, and where transformation did not correct for violations, non-parametric tests were used (see appendix Table 4 for details). One-tailed Spearman's rank-order correlations were used to examine the relationship between CD score and cognitive performance.

For schizophrenia-aphasia comparisons, we compared the degree of impairment in each patient group in relation to controls by standardising performance scores based on means and standard deviations of respective age-matched HCs (z-scores). Composite verbal cognition scores were calculated by averaging TROG-2 and BNT z-scores, and composite non-verbal cognition scores were calculated by averaging Matrix Reasoning, Brixton and PPT z-scores. Pearson's correlations were used to examine the relationship between verbal and non-verbal cognitive performance. Tests were two-tailed, unless stated otherwise. Alpha was set at .05. For tests measuring similar constructs (VCI and PRI), alpha was adjusted using the Bonferroni-Holm correction. SPSS for Windows (version 23; IBM Corp., 2013) was used.

Results

Table 1 displays demographics, clinical characteristics and mean cognitive scores for all groups. Table 2 displays results of ANOVA and multiple comparisons to test group differences.

Table 1. Demographics, clinical characteristics and mean cognitive test scores for each group.

	SZ	**SZ+FTD**	**SZ-FTD**	**FDR**	**HC_{sz}**	**Aphasia**	**HC_{aph}**
N	30	15	15	16	15	20	30
% Male	77	87	67	50	47	80	30
% White British	100	100	100	100	93	-	-
% Right Handed	87	80	93	88	100	100	93
Age in years	43.9(12.8)	49.9(14.6)	38.0(7.3)	44.9(12.6)	45.1(13.0)	63.7(10.7)	70.2(7.0)
Years of formal education	13.9(3.8)	14.8(3.6)	12.9(4.0)	16.7(4.0)	16.3(3.6)	13.9(2.2)	14.3(2.0)
Illness duration in months	215.7(121.8)	232.2(149.4)	199.2(88.6)	-	-	76.2(63.3)	-
PANSS Conceptual Disorganisation Score	3.4(2.0)	5.2(0.9)	1.5(0.6)	1.3(0.6)	1 .0(0.0)	-	-
PANSS Total Score	101.3(22.1)	114.4(19.4)	88.3(16.3)	52.7(20.4)	40.1(5.8)	-	-
NART Full IQ	95.2(13.9)	95.7(14.2)	94.7(14.0)	101.1(11.8)	109.1(8.7)	-	-
WASI-II Full Scale IQ-4	83.6(17.9)	80.3(15.7)	86.9(19.9)	103.0(9.5)	106.9(8.5)	-	-
VCI	81.8(15.8)	78.9(13.3)	84.7(18.0)	92.3(11.7)	102.3(7.8)	-	-

PRI	88.3(20.4)	85.0(20.0)	91.7 (21.0)	113.4(7.7)	110.1(11.9)	-	-
Matrix Reasoning	43.5(13.3)	39.8(12.9)	47.3(13.0)	62.4(7.8)	57.5(9.3)	49.4(10.1)	56.0(6.1)
TROG-2 Total Score	15.2(4.3)	13.7(5.1)	16.6(3.0)	17.4(2.7)	18.4(1.6)	12.0(5.0)	19.0(0.9)
BNT Overall Score	52.9(5.3)	53.1(5.0)	52.7(5.8)	55.9(2.7)	56.5(2.5)	40.8(15.4)	57.3(2.4)
Brixton Total Correct	26.2(10.5)	21.2(12.7)	30.5(6.0)	34.7(8.8)	38.2(7.2)	35.1(5.9)	38.0(5.6)
PPT Total Score	48.8 (3.4)	47.7(4.3)	49.8(1.7)	50.8(0.4)	50.9(0.9)	49.65(3.2)	50.5(1.5)

Data are reported as Mean (Standard Deviation). SZ = all participants with schizophrenia, SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, FDR = first-degree relatives, HC_{sz} = healthy controls matched to SZ, HC_{aph} = healthy controls matched to participants with aphasia, PANSS = Positive and Negative Syndrome Scale, NART = National Adult Reading Test, WASI-II = Wechsler Abbreviated Scale of Intelligence - Second Edition, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.

Table 2. Results of ANOVAs and multiple comparisons to test group differences in cognitive scores.

ANOVA with groups SZ, FDR, HC					**Multiple Comparisons (*p*)**		
Cognitive Test	Statistic	DF	*p*	ES	SZ vs FDR	SZ vs HC	FDR vs HC
VCI	$F = 16.99$	2,35.59	<.001*	$\omega^2 = .34$	.036*	<.001*	.026*
PRI	$F = 17.75$	2,34.84	<.001*	$\omega^2 = .35$	<.001*	<.001*	.637
TROG-2	$F = 6.22$	2,57	.004*	$\eta_p^2 = .18$	.060†	.001*	.171
BNT	$F = 5.27$	2,37.15	.010*	$\omega^2 = .12$	.014*	.009*	.910
Brixton	$F = 9.18$	2,45	.001*	$\eta_p^2 = .29$	.014*	<.001*	.254
PPT	$\chi^2 = 9.04$	2	.011*	$\eta^2 = .19$	.031*	.007*	.737
ANOVA with groups SZ+FTD, SZ-FTD, HC					**Multiple Comparisons (*p*)**		
Cognitive Test	Statistic	DF	*p*	ES	SZ+FTD vs SZ-FTD	SZ+FTD vs HC	SZ-FTD vs HC
VCI	$F = 1.83$	2,42	<.001*	$\eta_p^2 = .36$	.258	<.001*	.001*
PRI	$F = 7.77$	2,42	.001*	$\eta_p^2 = .27$	.319	<.001*	.008*
TROG-2	$F = 7.85$	2,41	.001*	$\eta_p^2 = .28$	.032*	<.001*	.084

BNT	F = 4.66	2,24.29	.019*	ω^2 = .14	.984	.063†	.076
Brixton	F = 11.89	2,34	<.001*	η_p^2 =.41	.056†	<.001*	.006*
PPT	χ^2 = 8.06	2	.018*	η^2 = .18	.554	.014*	.372
ANOVA with groups SZ+FTD, SZ-FTD, Aphasia					**Multiple Comparisons (*p*)**		
Cognitive Test (z-score)	Statistic	DF	*p*	ES	Aphasia vs SZ+FTD	Aphasia vs SZ-FTD	SZ+FTD vs SZ-FTD
Matrix Reasoning	F = 1.53	2,46	.227	η_p^2=.06	.120	.975	.149
TROG-2	F = 14.86	2,46	<.001*	η_p^2=.39	.011*	<.001*	.140
BNT	F = 9.99	2,47	<.001*	η_p^2=.30	<.001*	<.001*	.956
Brixton	F = 7.27	2,41	.002*	η_p^2=.26	<.001*	.154	.031*
PPT	F = 5.24	2,19.21	.015*	ω^2=.12	.026*	.230	.244

*significant at the .05 level. †trending towards significance. ANOVA = analysis of variance, SZ = all participants with schizophrenia, FDR = first-degree relatives, HC = healthy controls, SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, DF = degrees of freedom, ES = effect size, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.

Note: Comparisons of SZ+FTD and SZ-FTD groups are presented twice with slightly different results taken from two different models: firstly, neuropsychological scores of the two groups were compared with that of controls, and in a second model, neuropsychological scores of the two groups were standardised against matched controls, then compared with standardised scores of participants with aphasia.

Cognitive Impairment in Schizophrenia

To test H1, we compared cognitive performance of all patients with schizophrenia (SZ), FDRs and HC. Groups differed on PANSS total score (F(2,58)=65.24, p<.001, η_p^2=.69) and CD score (F(2,58)=17.46, p<.001, η_p^2=.38). For both measures, SZ had higher scores than FDRs and HC (all ps<.001). There were no differences in age (F(2,58)=8.74, p=.948, η_p^2=.002). Groups differed in years of education (F(2,58)=3.66, p=.032, η_p^2=.11), pmIQ (F(2,57)=6.39, p=.003, η_p^2=.18), and current IQ (F(2,58)=17.44, p<.001, η_p^2=.38). SZ had fewer years of education than FDRs (p=.020) and HC (trend level; p=.050), lower pmIQ than HC (p=.001), and lower current IQ than FDRs and HC (both ps<.001).

Standard deviations show that SZ had more variance in cognitive test scores than FDRs and HC. PPT data were analysed with non-parametric tests (SZ mean rank=19.3, FDRs mean rank=30.0, and HC mean rank=31.9). ANOVA revealed that groups differed on every test. SZ had lower scores than FDRs and HC on all tasks, except TROG-2 where the difference between SZ and FDRs was at a trend level. FDRs scored lower than HC on VCI only. Since groups differed in years of education and pmIQ, ANCOVA was also used, covarying for these variables (see appendix Table 5). In this case, the effect of group on TROG-2, PPT and BNT scores was no longer significant, and the SZ-FDR and FDR-HC differences in VCI were no longer significant.

Cognitive Impairment in FTD

To test H2, we compared cognitive performance of SZ+FTD, SZ-FTD and HC. Groups differed on PANSS total score (F(2,42)=94.41, p<.001, η_p^2=.82): SZ+FTD scored higher than SZ-FTD and HC, and SZ-FTD scored higher than HC (all ps<.001). Groups differed in age (F(2,42)=3.69, p=.033, η_p^2=.15): SZ+FTD were older than SZ-FTD (p=.010). The model indicated no differences in years of education (F(2,42)=2.99, p=.061, η_p^2=.13), however, post-hoc tests showed that SZ-FTD had fewer years of education than HC (p=.019). Groups differed in pmIQ (F(2,41)=6.07, p=.005, η_p^2=.23) and current IQ (F(2,42)=12.08, p<.001, η_p^2=.37); SZ+FTD and SZ-FTD scored lower than HC (pmIQ p=.006 and p=.003, respectively; current IQ p<.001 and p=.005, respectively).

PPT data were analysed with non-parametric tests (SZ+FTD mean rank=13.29, SZ-FTD mean rank=19.08, and HC mean rank=25.65). ANOVA revealed that groups differed on all tests. SZ+FTD scored lower than SZ-FTD on TROG-2 and the difference in Brixton scores was at trend level. SZ+FTD scored lower than HC on all tests, except BNT, where if difference was at trend level. SZ-FTD scored lower than HC on VCI, PRI and Brixton. After covarying for pmIQ and years of education (ANCOVA), the effect of group for PPT and BNT scores was no longer significant, SZ-FTD only scored lower than HC on Brixton, and SZ+FTD scored lower than SZ-FTD on VCI and Brixton (see appendix Table 6).

CD score (FTD) was negatively correlated with scores on VCI (ρ(28)=-.35, p=.031), PRI (ρ(28)=-.37, p=.023), Brixton (ρ(22)=-.36, p=.040), TROG-2 (ρ(27)=-.39, p=.019), and PPT (ρ(23)=-.36, p=.041), but not BNT (ρ(23)=-.26, p=.087), in all participants with schizophrenia (pooled). CD score did not correlate with any cognitive score in FDRs (see appendix Table 7).

Comparison with Aphasia

Independent samples t-tests revealed that the aphasia group scored lower than matched controls on Matrix Reasoning (t(27.01)=-2.57, p=.016, d=0.78), TROG-2 (t(22.81)=7.67, p<.001, d=2.38), BNT (t(22.63)=6.14, p<.001, d=1.91), and Brixton (t(45)=-2.31, p=.025, d=0.67), but not PPT (t(48)=.79, p=.435, d=0.22).

To test H3 and H4, we compared the cognitive performance of patients with SZ+FTD, SZ-FTD and aphasia. Table 3 and Figure 1 display mean cognitive z-scores for each group. ANOVA revealed that groups differed on all tests, except Matrix Reasoning. Participants with aphasia scored lower than SZ+FTD and SZ-FTD on TROG-2 and BNT. SZ+FTD scored lower than the aphasia group on Brixton and PPT, and scored lower than SZ-FTD on Brixton. When covarying for years of education (ANCOVA), groups also differed in Matrix Reasoning, with SZ+FTD scoring lower than aphasia and SZ-FTD participants, and SZ+FTD scored lower than SZ-FTD on TROG-2 and PPT (see appendix Table 8).

Table 3 displays composite verbal and non-verbal cognitive z-scores and Figure 2 illustrates the relationship between these in each group. Verbal and non-verbal performance correlated in SZ+FTD ($r(8)=.71$, $p=.022$) and SZ-FTD ($r(11)=.84$, $p<.001$), as well as when all participants with schizophrenia were pooled ($r(21)=.79$, $p<.001$), but not in aphasia patients ($r(17)=.11$, $p=.667$).

Table 3. Mean cognitive z-scores of participants with aphasia, SZ+FTD, and SZ-FTD.

	Aphasia		**SZ+FTD**		**SZ-FTD**	
	N	**Mean(SD)**	***N***	**Mean(SD)**	***N***	**Mean(SD)**
Verbal z-score	19	-7.6(5.6)	14	-2.3(2.3)	15	-1.3(1.7)
TROG-2 z-score	20	-7.7(5.5)	14	-2.9(3.2)	15	-1.1(1.9)
BNT z-score	20	-7.0(6.5)	15	-1.4(2.0)	15	-1.5(2.3)
Non-verbal z-score	19	-0.7(1.2)	11	-2.3(1.7)	13	-1.0(1.1)
Matrix Reasoning z-score	19	-1.1(1.6)	15	-1.9(1.4)	15	-1.1(1.4)
Brixton z-score	20	-0.5(1.0)	11	-2.4(1.8)	13	-1.1(0.8)
PPT z-score	20	-0.6(2.1)	12	-3.8(5.0)	13	-1.2(2.0)

Data are reported as Mean (Standard Deviation). SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees. Verbal z-score was calculated by averaging TROG-2 and BNT scores, and non-verbal z-score was calculated by averaging Matrix Reasoning, Brixton and PPT scores.

Fig 1. Mean cognitive z-scores for participants with aphasia, SZ+FTD, and SZ-FTD. Z-scores standardised against respective control groups (control mean = 0). Error bars = +/- 2 standard error. SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees s

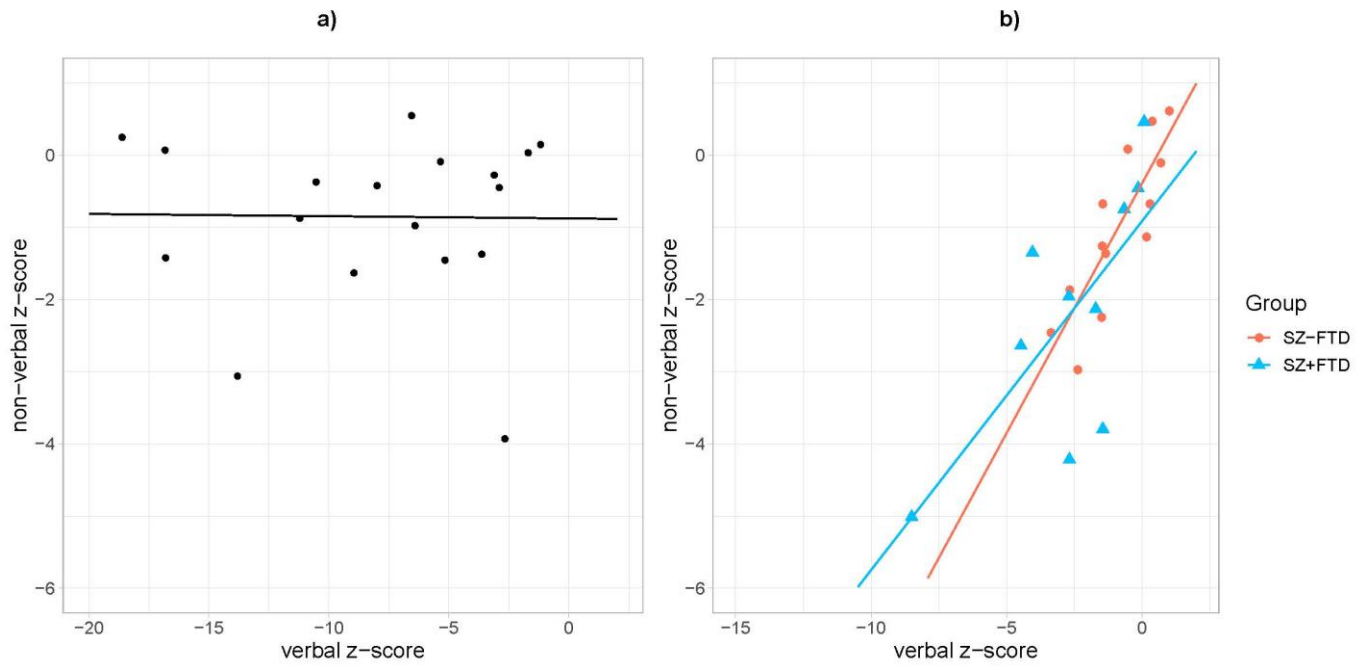

Fig 2. Scatter plots showing the relationship between verbal and non-verbal performance for participants with (a) aphasia and (b) schizophrenia with and without formal thought disorder (SZ+FTD and SZ-FTD, respectively).

Discussion

This study compared verbal and non-verbal cognitive profiles of schizophrenia patients with and without FTD and in patients with aphasia. The latter comparisons are novel and allow evaluation of claims that language impairments play a causal role in the cognitive impairment seen in schizophrenia. Results showed that, as hypothesised and largely in keeping with previous research (Barrera et al., 2005; Goldberg et al., 1998; Rodriguez-Ferrera et al., 2001; Schaefer et al., 2013; Stirling et al., 2006), schizophrenia was associated with impairment across all cognitive domains relative to controls. Deficits in EF and verbal and non-verbal intelligence (VCI and PRI) remained after accounting for pmIQ and years of education.

While both SZ+FTD and SZ-FTD showed deficits in VCI, PRI, and EF, there was a greater breadth of impairment in SZ+FTD, with additional deficits in picture-semantic memory and sentence comprehension, and more severe impairment in EF. The additional deficit in picture-semantic memory in SZ+FTD was inferred from a significant impairment (relative to controls) in SZ+FTD, whereas, in contrast with previous research (Doughty & Done, 2009; Lawrence et al., 2007), we did not demonstrate an impact of SZ-FTD on the PPT task. When directly compared, the SZ+FTD and SZ-FTD groups did not differ in PPT score, thus further investigation is needed. Results of previous studies examining semantic performance, including naming ability, in schizophrenia and FTD are heterogeneous (Barrera et al., 2005; Bora et al., 2019; Landre et al., 1992; Leeson et al., 2006; Rodriguez-Ferrera et al., 2001), with IQ, test used, illness chronicity and control matching methodology contributing to heterogeneity (Doughty & Done, 2009; Weickert et al., 2000). In our study, neither schizophrenia group showed deficits in naming and whilst the degree of FTD correlated with poor performance on almost all tests, BNT was the exception. Whilst previously identified contributors to variability need to be borne in mind, it is noteworthy that performance did not separate on the naming task, suggesting that the impairment associated with FTD may be specific to tasks requiring sentence comprehension. Overall, our hypothesis that FTD would be associated with more severe deficits across all tests was not supported.

Contrary to research suggesting cognitive impairment in FDRs of patients with schizophrenia (Bora et al., 2014), our FDR group displayed impairment only in verbal intelligence, and this difference disappeared when controlling for pmIQ and education.

As expected, the aphasia group displayed significant linguistic impairments, but also showed mild impairment on matrix reasoning and EF compared to neurotypical controls. There may be a number of reasons for this impairment, for example, loss of inner speech support might contribute to difficulties with matrix reasoning. However, naturally occurring brain lesions often disrupt the substrates of multiple cognitive mechanisms through direct damage or interruption of white matter tracts, leading to disconnection phenomena. Participants with aphasia showed more severe language deficits than both schizophrenia groups, consistent with research suggesting that schizophrenia and aphasia can be distinguished based on sentence comprehension and naming (Halpern & McCartin-Clark, 1984; Taylor, 1999). However, despite more marked language impairment in aphasia, there was a dissociation with degree and breadth of non-verbal cognitive impairment. Verbal and non-verbal performance were strongly correlated in both schizophrenia groups but not in the aphasia group. These data suggest caution in assuming that cognitive impairment in schizophrenia is a consequence of language disruption. Instead, verbal and non-verbal impairment may be part of a generalised cognitive decline that impacts on multiple domains. However, communicative ability may remain a valid target in cognitive remediation strategies in schizophrenia.

There are a number of caveats with regard to these findings and preliminary conclusions. Since sample sizes were limited, we suggest replication to confirm these findings. Measuring degree of FTD with PANSS CD may

also be problematic: FTD is associated with clinical severity of schizophrenia (Roche et al., 2015) and SZ+FTD showed higher PANSS total scores than SZ-FTD. It is therefore possible that the cognitive deficit in SZ+FTD, rather than reflecting a qualitative difference (which would suggest that SZ+FTD represents a distinct subgroup of schizophrenia), may be a quantitative difference, reflecting clinical severity of schizophrenia, rather than FTD, per se. Similarly, grouping participants based on FTD may itself be problematic. However, the negative correlations of CD score and scores on all cognitive tests (except BNT) support the results generated by group comparisons.

Our analysis of impairment was relational, i.e. we compared the deviation of each clinical group from its matched control group. The motivation for that was that participants with schizophrenia differed from participants with aphasia substantially in age, location, and test protocol. Thus, similar test scores across clinical groups can be interpreted as different degrees of impairment, dependent on the performance from their respective control groups. SZ+FTD and aphasic groups had similar scores on grammatical comprehension (TROG-2; Table 1), but in relation to respective controls, the deviation in aphasia was significantly greater and the impairment was therefore judged as greater. This was caused by the aphasia-matched control group scoring higher and showing less variance than the schizophrenia-matched control group. This difference may be because of an accuracy increase associated with ageing, or because of methodological differences (e.g. location and experimenter) and sample characteristics (e.g. dialect) between the two control samples.

Since healthy controls were matched to the whole group of patients with schizophrenia, rather than the SZ+FTD group specifically, this should be borne in mind when comparing scores of the control group and SZ+FTD. Also, since groups differed on years of education and pmIQ, results of ANCOVA controlling for these variables were also reported. However, pmIQ and education may not be independent of schizophrenia (e.g. schizophrenia symptoms interfering with educational attainment), and our a priori predictions did not include these variables, therefore we focused primarily on results generated by ANOVA. Likewise, since we tested verbal and non-verbal intelligence (VCI and PRI), we did not control for current IQ. Intelligence has been linked to cognitive and language performance (Landre et al., 1992; Rodriguez-Ferrera et al., 2001), and there may be a subgroup of schizophrenia patients with relatively spared IQ who do not show cognitive deficits (Weickert et al., 2000). A few participants with schizophrenia in our sample displayed relatively high IQ, therefore, these may have been 'cognitively preserved' patients whose performance could have skewed results. Other factors affecting language and cognition in schizophrenia that we did not control for include gender, symptomology, medication, age at admission and duration of illness (Amminger, Edwards, Brewer, Harrigan, & McGorry, 2002; Landre et al., 1992).

The standardised tests employed in our investigation have advantages, such as easy reproducibility, but they are limited in the degree of specificity in identifying both verbal and non-verbal impairment. For example, in the case of the language probes, both picture naming and sentence-to-picture matching are proxy measures that subsume multiple sub-processes. Grammar, for instance, is a highly complex process that involves the ability to conceive or comprehend a complex message, select grammatical frames and integrate lexical complexity, and track sequences and structural dependencies within fractions of a second. More sensitive probes might reveal differences between language dysfunction in aphasia and schizophrenia and such differences might be critical mediators of performance in other cognitive domains. Future research should employ different methods to focus on these capacities and determine which are linked to general cognitive impairment. For example, studies should measure core functions of language, such as reference and propositional meaning (Zimmerer et al., 2017), and use implicit language measures, such as priming and reaction time tasks, in addition to explicit measures like those used here.

It is also important to consider the interrelatedness of cognitive processes. While research suggests a generalised cognitive decline in schizophrenia (Schaefer et al., 2013), and our results suggest widespread cognitive impairment, it is possible that a specific cognitive impairment is responsible for poor performance in other cognitive tasks. For example, some suggest that observed working memory deficits could reflect deficits in inhibition (Eich, Nee, Insel, Malapani, & Smith, 2014), and that executive dysfunction is responsible for poor performance of patients with schizophrenia in a processing speed task (Knowles et al., 2015). Future research into cognitive impairment in schizophrenia and aphasia would benefit from techniques from experimental cognitive psychology to more accurately measure cognitive deficits and examine their interaction.

Overall, these data reveal that, when using standardised tests, language impairment occurs in aphasia, in SZ+FTD and in SZ-FTD. Language was more impaired in aphasia than in schizophrenia, but another key difference between these groups lies in the specificity of the language performance, i.e. the degree to which it is integrated with impairment on other cognitive tasks, as well as the nature of this impairment. Aphasia and schizophrenia, particularly in those with FTD, is associated with impaired sentence understanding as measured by TROG-2, but while patients with aphasia show a more severe impairment with relatively preserved non-verbal performance, SZ+FTD participants have a broader pattern of cognitive impairment. Thus, the degree to which impaired language use is associated with other cognitive abilities varies across pathological populations to the point that the group most severely impaired in the language tests was the least impaired in non-verbal tests. In this way, whether a poor language score means that there is a more general cognitive impairment depends on the population. This may either be because language impairment is qualitatively different in schizophrenia compared to aphasia, being an expression of a fundamentally altered cognition in the former case but not the latter; or, in a more dualistic framework, it may be that language output can be disrupted because of direct damage to different systems. These results stress the need for more sophisticated linguistic profiling of language capacities in schizophrenia and FTD so as to understand the link to cognition and thought that they involve in this disorder. This insight would further illuminate the foundational question of the role of language in cognition.

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Disclosure of interest

No potential conflict of interest was reported by the authors.

Data availability statement

The authors confirm that the data supporting the findings of this study are available in the supplementary materials.

Author Contributions

This paper was conceived by WH, SW, RV and VZ. Test protocols were devised by INF, WH, HS, FD, DT, RV and VZ. MD, HS, DT and SW managed and carried out recruitment and assessment of participants with schizophrenia, FDRs and respective controls. RV and VZ recruited aphasic participants and respective controls, VZ assessed participants. DC cleaned and managed the data. BL analysed the data with support from PG, SW, VZ, RV and WH. BL wrote the first draft of the paper. BL, DC, DT, FD, INF, PG, RV, SW, VZ and WH contributed to drafts of the manuscript. The work was supported by a project grant to WH, DT and RV, for which WH is the PI.

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Appendix

Table 4. Details of data transformations and statistical models used for each stage of the analysis.

Data	Statistical model used	Data transformed	Reason
H1) Comparison of cognitive performance of pooled SZ group, FDRs and matched controls			
WASI-II VCI	Welch's ANOVA and Games-Howell post-hoc tests	N/A	Variances not homogeneous
WASI-II PRI	Welch's ANOVA and Games-Howell post-hoc tests	N/A	Variances not homogeneous
TROG-2 score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and log transform	Negatively skewed, outliers
BNT score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Winsorization of outlier(s)	Outlier
Brixton score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Winsorization of outlier(s)	Negatively skewed, outliers
PPT score	Kruskal-Wallis H test and Dunn's pairwise comparisons	N/A	Negatively skewed, outliers (transformation did not correct violations of assumptions)
H1) Comparison of cognitive performance of pooled SZ group, FDRs and matched controls, controlling for years of education and pmIQ			

WASI-II VCI	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Comparison ANCOVA with outlier removed – result the same	Outlier
WASI-II PRI	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Square transform	Heteroscedastic
TROG-2 score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and log transform	Negatively skewed, outliers, heteroscedastic
BNT score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and log transform	Outliers, heteroscedastic
Brixton score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed
PPT score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed, outliers, heteroscedastic
H2) Comparison of cognitive performance of SZ+FTD, SZ-FTD and matched controls			
WASI-II VCI	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	N/A	N/A
WASI-II PRI	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Winsorization of outlier(s)	Outlier
TROG-2 score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed, outliers, variances not homogeneous
BNT score	Welch's ANOVA and Games-Howell post-hoc tests	N/A	Variances not homogeneous

Brixton score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed, outliers, variances not homogeneous
PPT score	Kruskal-Wallis H test and Dunn's pairwise comparisons	N/A	Negatively skewed, outliers, variances not homogeneous (transformation did not correct violations of assumptions)
H2) Comparison of cognitive performance of SZ+FTD, SZ-FTD and matched controls, controlling for years of education and pmIQ			
WASI-II VCI	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	N/A	N/A
WASI-II PRI	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	N/A	N/A
TROG-2 score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed, outliers, heteroscedastic
BNT score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed, heteroscedastic
Brixton score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transformation	Negatively skewed, heteroscedastic
PPT score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and inverse transform	Negatively skewed, heteroscedastic, outliers
H2) Correlation of Conceptual Disorganisation (CD) score and cognitive performance in SZ			
WASI-II VCI	Spearman's rank-order correlation (one-tailed)	N/A	Data skewed

WASI-II PRI	Spearman's rank-order correlation (one-tailed)	N/A	Data skewed
TROG-2 score	Spearman's rank-order correlation (one-tailed)	N/A	Data skewed
BNT score	Spearman's rank-order correlation (one-tailed)	N/A	Data skewed
Brixton score	Spearman's rank-order correlation (one-tailed)	N/A	Data skewed
PPT score	Spearman's rank-order correlation (one-tailed)	N/A	Data skewed
H3) Comparison of cognitive performance of aphasia patients and matched controls			
WASI-II Matrix Reasoning	Independent t-test (equal variances not assumed)	N/A	Variances not homogeneous
TROG-2 score	Independent t-test (equal variances not assumed)	Reflect and square-root transform	Data skewed, outliers, variances not homogeneous
BNT score	Independent t-test (equal variances not assumed)	Reflect and square-root transform	Data skewed, outliers, variances not homogeneous
Brixton score	Independent t-test	Winsorization of outlier(s)	Outlier
PPT score	Independent t-test	Reflect and log transform	Data skewed, outliers, variances not homogeneous
H3) Comparison of cognitive z-scores of aphasia patients, SZ+FTD and SZ-FTD			
WASI-II Matrix Reasoning	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	N/A	N/A

TROG-2 score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Winsorization of outlier(s)	Outliers
BNT score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and log transform	Negatively skewed, variances not homogeneous
Brixton score	ANOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Variances not homogeneous
PPT score	Welch's ANOVA and Games-Howell post-hoc tests	Winsorization of outlier(s)	Negatively skewed, outliers variances not homogeneous
H3) Comparison of cognitive z-scores of aphasia patients, SZ+FTD and SZ-FTD, controlling for years of education			
WASI-II Matrix Reasoning	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	N/A	N/A
TROG-2 score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and log transform	Negatively skewed, heteroscedastic
BNT score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and log transform	Negatively skewed, heteroscedastic
Brixton score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Variances not homogeneous
PPT score	ANCOVA and pairwise comparisons with Fisher's Least Significant Difference	Reflect and square-root transform	Negatively skewed, heteroscedastic, outliers
H4) Correlation of (composite) verbal and non-verbal performance of aphasia patients, SZ+FTD and SZ-FTD			

Verbal performance	Pearson's correlation	N/A	N/A
Non-verbal performance	Pearson's correlation	N/A	N/A

ANOVA = analysis of variance, ANCOVA = analysis of covariance SZ = all participants with schizophrenia (pooled), FDR = first-degree relatives, SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, WASI-II = Wechsler Abbreviated Scale of Intelligence - Second Edition, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.

Table 5. Results of ANCOVA and multiple comparisons to test differences between SZ, FDR and HC groups on each cognitive test, controlling for NART Full IQ and years of formal education.

Cognitive Test	**ANCOVA**					**Multiple Comparisons (*p*)**		
		F	**DF**	***p***	η_p^2	**SZ < FDR**	**SZ < HC**	**FDR < HC**
WASI-II VCI	Model	13.15	4,55	<.001*	.49	.113	.001*	.086
	Group	5.76	2,55	.005*	.17			
	Education	3.89	1,55	.054†	.07			
	NART	4.36	1,55	.041*	.07			
WASI-II PRI	Model	13.24	4,55	<.001*	.49	<.001*	.019*	.253
	Group	8.30	2,55	<.001*	.23			
	Education	2.51	1,55	.119	.04			
	NART	4.67	1,55	.035*	.08			
TROG-2 Total	Model	4.88	4,54	.002*	.27	.235	.065†	.462
Score	Group	1.90	2,54	.160	.07			
	Education	<.001	1,54	.969	<.001			
	NART	4.68	1,54	.035*	.08			
BNT Overall	Model	14.27	4,55	<.001*	.51	.491	.847	.679
Score	Group	0.24	2,55	.785	.01			
	Education	1.34	1,55	.252	.02			
	NART	21.18	1,55	<.001*	.28			
Brixton Total	Model	5.27	4,42	.002*	.33	.046*	.001*	.213
Correct	Group	6.17	2,42	.004*	.23			
	Education	4.44	1,42	.041*	.10			

	NART	1.10	1,42	.300	.03			
PPT Total	Model	3.54	4,43	.014*	.25	.142	.052†	.676
Score	Group	2.30	2,43	.112	.10			
	Education	2.00	1,43	.164	.04			
	NART	0.15	1,43	.703	<.001			

*significant at the .05 level. †trending towards significance. ANCOVA = analysis of covariance, DF = degrees of freedom, NART = National Adult Reading Test, SZ = all participants with schizophrenia, FDR = first-degree relatives, HC = healthy controls, WASI-II = Wechsler Abbreviated Scale of Intelligence - Second Edition, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.

Table 6. Results of ANCOVA and multiple comparisons to test differences between SZ+FTD, SZ-FTD and HC groups on each cognitive test, controlling for NART Full IQ and years of formal education.

Cognitive Test		ANCOVA				Multiple Comparisons (*p*)		
		F	**DF**	***p***	η_p^2	**SZ+FTD < SZ-FTD**	**SZ+FTD < HC**	**SZ-FTD < HC**
WASI-II VCI	Model	11.98	4,39	<.001*	.55	.047*	<.001*	.059†
	Group	7.43	2,39	.002*	.28			
	Education	5.14	1,39	.029*	.12			
	NART	1.57	1,39	.217	.04			
WASI-II PRI	Model	8.42	4,39	<.001*	.46	.123	.012*	.253
	Group	3.51	2,39	.040*	.15			
	Education	2.53	1,39	.120	.06			
	NART	3.09	1,39	.087	.15			
TROG-2 Total Score	Model	4.66	4,38	.004*	.33	.052†	.017*	.494
	Group	3.46	2,38	.042*	.15			
	Education	0.02	1,38	.879	.001			
	NART	2.17	1,38	.149	.05			
BNT Overall Score	Model	8.76	4,39	<.001*	.47	.585	.903	.528
	Group	0.12	2,39	.889	.01			
	Education	0.34	1,39	.556	.01			
	NART	13.49	1,39	.001*	.26			
Brixton Total Correct	Model	6.61	4,31	.001*	.46	.017*	<.001*	.017*
	Group	10.21	2,31	<.001*	.40			

	Education	3.15	1,31	.086	.09			
	NART	1.09	1,31	.304	.03			
PPT Total Score	Model	4.63	4,32	.005*	.37	.093	.807	.178
	Group	1.64	2,32	.209	.09			
	Education	3.70	1,32	.063†	.10			
	NART	1.18	1,32	.286	.04			

*significant at the .05 level. †trending towards significance. ANCOVA = analysis of covariance, DF = degrees of freedom, NART = National Adult Reading Test, SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, HC = healthy controls, WASI-II = Wechsler Abbreviated Scale of Intelligence - Second Edition, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.

Table 7. Results of one-tailed Spearman's correlations of Conceptual Disorganisation score and neuropsychological scores in the first degree relatives of patients with schizophrenia.

Cognitive Test	**Spearman's correlation**
WASI-II VCI	$\rho(14) = -.190$, $p = .241$
WASI-II PRI	$\rho(14) = .222$, $p = .204$
TROG-2 Total Score	$\rho(14) = -.030$, $p = .455$
BNT Overall Score	$\rho(14) = -.165$, $p = .271$
Brixton Total Correct	$\rho(9) = -.225$, $p = .253$
PPT Total Score	$\rho(9) = -.190$, $p = .288$

WASI-II = Wechsler Abbreviated Scale of Intelligence - Second Edition, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.

Table 8. Results of ANCOVA to test group differences in cognitive z-scores between participants with aphasia, SZ+FTD and SZ-FTD, controlling for years of formal education.

Cognitive Test		ANCOVA				Multiple Comparisons (*p*)		
		F	**DF**	***p***	η_p^2	**Aphasia vs SZ+FTD**	**Aphasia vs SZ-FTD**	**SZ+FTD vs SZ-FTD**
Matrix Reasoning z-score	Model	4.85	3,45	.005*	.24	.037*	.743	.026*
	Group	3.23	2,45	.049*	.13			
	Education	10.84	1,45	.002*	.13			
TROG-2 z-score	Model	10.72	3,45	<.001*	.42	.004*	<.001*	.034*
	Group	15.69	2,45	<.001*	.41			
	Education	1.88	1,45	.178	.04			
BNT z-score	Model	8.25	3,46	.001*	.35	.001*	<.001*	.718
	Group	10.62	2,46	<.001*	.32			
	Education	3.63	1,46	.063†	.07			
Brixton z-score	Model	4.95	3,40	.005*	.27	<.001*	.179	.027*
	Group	7.34	2,40	.002*	.27			
	Education	0.49	1,40	.488	.01			
PPT z-score	Model	4.29	3,41	.010*	.24	.003*	.519	.029*
	Group	5.11	2,41	.010*	.20			
	Education	3.85	1,41	.056†	.09			

*significant at the .05 level. ANCOVA = analysis of covariance, DF = degrees of freedom, SZ+FTD = schizophrenia with formal thought disorder, SZ-FTD = schizophrenia without formal thought disorder, TROG-2 = Test for Reception of Grammar, BNT = Boston Naming Test, PPT = Pyramids and Palm Trees.